Journal of Agricultural Biotechnology and Sustainable Development Vol. 3(10), pp. 198-204, December 2011
Available online at http://www.academicjournals.org/JABSD
DOI: 10.5897/JABSD10.030


*Full Length Research Paper*

# Effects of nitrogen and phosphorus fertilizers and cotyledon removal on establishment and growth of yeheb nut bush (*Cordeauxia edulis* Hemsl.) outside its natural habitat

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Accepted 13 September, 2011

**Yeheb nut bush (*Cordeauxia edulis*) is a multipurpose but endangered shrub native to arid south-Eastern Ethiopia and Central Somalia. Establishment of this species was studied in two sets of experiments during 2005 to 2007. In the first set of experiment, field establishment was conducted at Dire Dawa, Ethiopia, which is located 725 km north west of the natural habitat (Bokh). Nitrogen at 0, 46 and 92 level and phosphorus at 0, 4 and 8 kg ha$^{-1}$ were applied 84 days after transplanting. Application of 92 N/8 P kg ha$^{-1}$ increased seedling height by 134%; 46 N/4 P kg ha$^{-1}$ increased leaf area by 152% and dry weight of seedlings increased by 309% at 46/8 kg ha$^{-1}$ NP compared to the unfertilized plants. Nitrogen and phosphorus fertilizers significantly altered soil as well as plant tissue N and P contents. Leaf and root N was significantly highest at 46 and 92 N kg ha$^{-1}$, respectively while leaf P was maximised at 8P kg ha$^{-1}$. In the second set, the impact of cotyledon removal was assessed in the greenhouse, Haramaya University by excision of cotyledon at 7 days interval for ten consecutive weeks and leaving the cotyledon with plant as a control. Removing cotyledon at 7, 14 and 35 days after germination (DAG) significantly reduced most of the growth parameters while seedlings with intact cotyledon had the highest dry matter accumulated. Thus, 46 to 92 kg N and 8 kg P ha$^{-1}$ would help the establishment and growth of *C. edulis* in the field and seedlings should retain cotyledon during early establishment. However, more rates of N and P as well as methods and frequency of applications deserve further investigation.**

**Key words:** *Cordeauxia edulis*, cotyledon, Ethiopia, nitrogen and phosphorus fertilizers, seedling establishment.

## INTRODUCTION

Yeheb nut bush (*Cordeauxia edulis*) is leguminous, multi-stemmed and evergreen shrub limited to arid south-eastern Ethiopia near Bokh and central Somalia (Seegeler, 1983; Booth and Wickens, 1988; Zimsky, 1990). It typically experiences erratic rainfall as low as 100 to 200 mm year$^{-1}$, average annual temperature of 28°C and grows at altitudes of 300 to 1000 m.a.s.l (Drechsel and Zech, 1988). *C. edulis* adapted to nutrient impoverished soil (Seegeler, 1983; Drechsel and Zech, 1988) and frost free areas. It is the only species within the genus *Cordeauxia*.

The seed of *C. edulis* is nutritious and tasty with a chestnut flavour. They contain 37% starch, 24% low molecular weight sugar, 13% proteins, 11% fats and various mineral salts (Gutale and Ahmed, 1984). The nut is the staple food for the local people which is liked to the common diet of rice and dates (Kazmi, 1979). The nut has also medicinal value and economic importance at

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local market and even across the continent (Booth and Wickens, 1988). In general, *C. edulis* has multiple uses: as fodder, firewood, house construction, bee food supply, mulch, soil conservation, live fence, dyes etc. (Azene et al., 1993). Moreover, it is a very drought tolerant and often represents the last existing perennial. The palatable leaves are dry season browse for animals (Drechsel and Zech, 1988). Further, *C. edulis* has the potential to be a reliable source of protein and valuable food crop in hot and dry regions (Zimisky, 1990). It could be particularly important for places where rainfall is scares for growing more conventional crops (Vietmeyer, 1985).

However, *C. edulis* is threatened by extinction in its natural habitat because of wars, recurrent drought, over-harvesting and heavy grazing (Miége and Miége, 1978; Zimsky, 1990). Thus, introduction of this multipurpose shrub to arid and semiarid tropics is greatly in need to minimize the threatening of this species.

One of the conditions which influence establishment and growth of plants is soil fertility. Nitrogen and phosphorus are among the major essential nutrient elements for improving plant growth and development. Olaniyi (2008) reported that various levels of individual and combined N and P fertilizers significantly improved growth and seed yield of *Citrullus lanatus*. Mhango et al. (2008) showed the importance of NPK fertilizer in improving seedling growth of *Uapaca kirkiana*. Similarly, *Picea glauca* growth and nutrient uptake increased by application of N fertilizer during its seedling stage (Mcalister and Timmer, 1998). *C. edulis* native area is characterized by red coloured sandy soil which is extremely low in nitrogen (Drechsel and Zech, 1988; Zimisky, 1990). According to Sassaki and Felipe (1998) *Dalbergia miscolobium* Benth which is occurring on a very poor soil responded positively to the addition of mineral nutrients when the plants were grown in pots. In another study, seedling growth of *Acacia auriculiformis* was enhanced significantly with the application of phosphorus fertilizers (Uddin et al., 2007). There might be a possibility of increasing establishment of *C. edulis* through supplying fertilizer.

Rate of fertilizers is considered as one of the factors that affect plants growth. According to Hossain and Hamid (2007), growth and yield of groundnut exhibited improved growth and yield with increased rate of N and P application. Jeppsson (2000) reported that vegetative growth and yield of *Aronia melanocarpa* increased with a combined application of NPK fertilizer in different rates.

The other factor which affects establishment of plants is the seed nutrient reserve (cotyledon). Large seeded species, including *C. edulis* (1.8 to 2.4 g dwt seed$^{-1}$; Andersson et al., 2007) rely heavily on nutrient support from the cotyledon than from the soil (Milberg and Lamont, 1997; Vaughton and Ramsey, 2001) to survive under unfavourable conditions and hazards during the establishment phase (Frost and Rydin, 1997; Kidson and Westoby, 2000). However, loss or damage of cotyledon could be brought by herbivores, insect pests and diseases. Large numbers of seedlings of *C. edulis* are destroyed by goats and camels during browsing (Johnson, 1996) and re-growth of grazed seedlings may be dependent on nutrient reserve. Milberg and Lamont (1997) reported that the effect of cotyledon removal was least in the smallest–seeded *Eucalyptus loxophleba* Benth and greatest in the largest-seeded, *Haeka psilorrhyncha* R. M. Barker. Taylor et al. (2006) animal browse protection is considered indispensable for successful seedling establishment of *Quercus*.

It is a prerequisite to know the stage at which cotyledon loss or damage might bring significant impact on seedling establishment of *C. edulis* to enable take measure at that specific time or phase. Therefore, the aim of this study was to determine the influence of NP fertilizers on *C. edulis* growth and to assess the importance of cotyledon to *C. edulis* establishment.

## MATERIALS AND METHODS

### Experimental locations and seed material

The field experiment (Experiment 1) was conducted at Dire Dawa, Ethiopia (09° 31'N, 41° 51' E), about 500 km east of the capital, Addis Ababa, and 725 km west of the natural habitat at an altitude of 1160 m.a.s.l. The experimental site is characterized as semi-arid tropical climate with average annual rainfall of about 644 mm (NMA, 2006). The rainfall has a bi-modal distribution pattern with small rains from March to May and long and moderate rains from June to September. The experimental soil is alluvial with a sandy clay loam to sandy loam texture and a pH of 8.6. The physic-chemical characteristics of the experimental and the native soils are shown in Table 1.

Plots were selected for the field experiment from a large piece of grazing land covered with grass during the previous nine years and fertilized with animal manure for four years preceding the study. The experimental plots were prepared by digging the soil to one meter depth preceding planning.

Experiment 2 was conducted in a greenhouse at Haramaya University, Ethiopia (9°26' N, 42°3' E).

The fruits of *C. edulis* were collected from natural vegetation in Gambarey village near Bokh town (7°22`N, 46° 35`E), Warder Zone of Eastern Ethiopia, 725 km south east of the study site, Dire Dawa. The fruits were gently dried in shade after harvest; the pericarps were removed and the seeds were kept in cotton-cloth bag at room temperature until used for the experiments.

### Experiment 1: Nitrogen and phosphorus fertilizer supply

The treatments consisted of 3 levels of N (0, 46, 92 kg ha$^{-1}$) and 3 levels of P (0, 4, 8 kg ha$^{-1}$) using urea (46% N) and triple super phosphate (20% P) as a source of N and P, respectively. Nine treatment combinations (0N0P, 0N4P, 0N8P, 46N0P, 46N4P, 46N8P, 92N0P, 92N4P and 92N8P kgha$^{-1}$) were laid out in a randomised complete block design in three replications.

Seedling were raised from ca 1400 seeds which were peeled fourteen days after harvest and sown on 20 June 2005 in a greenhouse. One seed was sown per polyethylene bag in partially-buried position after the bag was filled with sieved river sand and well watered. The bags were open-ended on both sides and had a size of 1.05 L by volume with a height of 0.12 m. After sowing, the

**Table 1.** Physicochemical characteristic of the experimental soil and the native soil.

| Parameter | Experimental soil (Dire Dawa) | | | | Native soil |
|---|---|---|---|---|---|
| | depth (cm) | | | | |
| | 0-25 | 25-75 | 75-123 | 123-200 | 0-20 |
| Texture | Sandy clay loam | Sandy loam | Loamy sandy | Sandy loam | Sandy |
| pH ($H_2O$) | 8.70 | 8.20 | 8.90 | 8.70 | 8.50 |
| EC (µs/cm) | 136.90 | 504.80 | 137.30 | 274.50 | 74.10 |
| Total nitrogen (%) | 0.042 | 0.042 | 0.014 | 0.028 | 0.014 |
| Available P (mg/kg soil) | 2.39 | 3.05 | 0.35 | 1.15 | 0.13 |
| Organic carbon (%) | 0.85 | 0.77 | 0.57 | 0.66 | 0.51 |
| CEC (meq/100 g soil) | 21.80 | 21.00 | 20.80 | 20.80 | 21.60 |
| Exchangeable bases mg (cmol (+) kg/soil | 2.89 | 1.50 | 0.77 | 1.88 | 1.18 |
| Exchangeable bases Na (cmol (+) kg/soil | 0.23 | 0.15 | 0.13 | 0.44 | 0.07 |
| Exchangeable bases Ca (cmol (+) kg/soil | 7.81 | 31.39 | 16.39 | 20.14 | 3.04 |
| Exchangeable bases Mg (cmol (+) kg/soil | 2.89 | 1.5 | 0.77 | 1.88 | 1.18 |
| Exchangeable bases K (cmol (+) kg/soil | 0.35 | 0.17 | 0.10 | 0.18 | 0.32 |
| $CaCO_3$ (%) | 6.70 | 7.00 | 4.70 | 6.70 | 0.90 |

polyethylene bags were covered with plastic sheets to maintain the moisture and they were removed after majority of the seeds had germinated.

Twelve seedlings of one month old were transplanted per plot (2.4 $m^2$) spaced 50 cm between rows and 40 cm between plants. The seedlings were planted in shallow moistened holes, exposing the cotyledon at the surface without covering with soil. Dead or weak seedlings were replaced with vigorous seedlings of similar age a week after transplanting. The nitrogen and phosphorus fertilizers were applied in splits: 11 weeks after transplanting and 44 weeks after the first application. Weeding and hoeing were done as required. Watering was done through furrows along the edges of each experimental plot and between plants for a few weeks then during the remaining experimental period, watering was continued by showering each plot twice a day. Eighty weeks after transplanting, plant height, stem diameter, root diameter, number of leaves, leaf area, fresh weight and dry weight were recorded on four randomly harvested plants per plot.

The amount of NP adsorbed by the soil was assessed by taking soil samples from the experimental field three times: Before planting, ten months and six months after the first and second fertilizer application, respectively. All the samples were taken from 0 to 30, 30 to 60 and 60 to 90 cm depths from each plot. The soil samples were air-dried, sieved with a 2 mm mesh size and analyzed for the total nitrogen and available phosphorus. Total nitrogen was determined according to the procedure of Kjeldahl (1883) and available phosphorus was determined according to Olsen et al*.* (1954) method.

To determine the amount of NP taken by the plant, four randomly harvested plants per plot were separated into leaf, stem, roots and dried at 70℃ until constant weighs was attained. T he dried biomass was analyzed for nitrogen and phosphorus contents. The dry matter was decomposed through wet ashing using the procedure of Kjeldahl (1883). Total N was determined by distillation of an aliquote from the digest with NaOH, collecting the distillate in boric acid and titrating with 0.1 $H_2SO_4$ to the end point of the mixed indicator. Determination of phosphorus was carried out on digest aliquots obtained through wet digestion. The phosphorus in the solution was determined colorimetrically using molybdate and metavanadate for color development. The reading was made at 460 Nm wavelength. Both analyses were done at the soil laboratory of Haramaya University.

#### Experiment 2: Date of cotyledon removal

Treatments comprised of ten cotyledon removal dates: 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days after germination (DAG) and seedlings with cotyledon left intact were used as a control. The treatments were arranged in a completely randomised design with four replications. Ten seeds per treatment and two seeds per pot (5 L) were sown after filled with sieved moistened river sand on 17 June 2006 in a greenhouse. The pots were covered with plastic sheets until most of the seeds per pot had germinated. Plant height, root length, stem diameter, root diameter, leaf number, leaf area, fresh weight and dry weight of the seedlings were measured and recorded on three plants per replication after five months.

#### Statistical analysis

The effect on plant height, root length, stem diameter, root diameter, leaf area, dry weight, soil and leaf, stem, root NP content was tested. Analysis of variance for both experiments was carried out using the General Linear Model of Minitab Statistical Software and when the ANOVA showed significant treatment effects, the means were compared using the least significant difference test at 5% level of significance.

## RESULTS AND DISSCUSION

### Experiment 1: Nitrogen and phosphorus fertilizer supply

Application of nitrogen and phosphorus fertilizers had significant effect on the growth of *C. edulis* (Table 2) but did not affect number of survived seedlings (data not shown). Plant height and stem diameter were maximised at the application rate of 92 kg $ha^{-1}$ nitrogen and 8 kg $ha^{-1}$

**Table 2.** Effect of NP fertilizer on growth of *C. edulis* seedlings.

| Treatment | | Plant height (cm) | Stem diameter (mm) | Root diameter (mm) | Leaf area ($cm^2$) | Dry weight of seedling (g) |
|---|---|---|---|---|---|---|
| N (kg $ha^{-1}$) | P (kg $ha^{-1}$) | | | | | |
| 0 | 0 | 10.5 | 2.7 | 2.4 | 34.1 | 3.3 |
| 0 | 4 | 11.6 | 3.1 | 2.8 | 49.3 | 4.6 |
| 0 | 8 | 11.2 | 2.6 | 2.4 | 36.3 | 3.9 |
| 46 | 0 | 13.4 | 2.9 | 2.8 | 36.1 | 5.9 |
| 46 | 4 | 17.2 | 4.1 | 4.2 | 86.0 | 12.8 |
| 46 | 8 | 13.4 | 4.0 | 3.8 | 53.8 | 13.5 |
| 92 | 0 | 12.7 | 3.6 | 3.3 | 34.7 | 8.7 |
| 92 | 4 | 18.1 | 3.9 | 3.7 | 84.9 | 12.6 |
| 92 | 8 | 24.6 | 4.2 | 3.7 | 67.4 | 12.9 |
| N | | ** | ** | ** | ** | *** |
| P | | * | ** | ** | *** | ** |
| LSD (5%) N*P | | 1.17 | 0.52 | 0.52 | 16.61 | 2.91 |

Ns, Non- significant,*, **,***, significant at P = 0.05, P = 0.01 and P = 0.001, respectively.

phosphorus which were about 134 and 55%, respectively, over the unfertilized plot. Beside flower development of *C. edulis* was recorded at this rate. In agreement with this result, biomass of *Sarcobatus vermiculatus* seedlings was doubled by fertilizer application compared to controls (Breen and Richards, 2008). Hashimi and Hughes (2010) also showed that enhanced growth of *Glochidion obscurum* and *Lagerstroemia speciosa* at high rate of NPK. Root diameter and leaf area were highest at 46 kg $ha^{-1}$ N and 4 kg $ha^{-1}$ P while maximum dry weight of seedlings were recorded at 46 kg $ha^{-1}$ N and 8 kg $ha^{-1}$ P. Nitrogen and phosphorus elements have tremendous roles in plant nutrition in which phosphorus stimulates the formation of lateral and fibrous roots that increases the absorbing surface for nutrients while nitrogen increases the cation exchange capacity of plant roots to use more phosphorus including potash and calcium (Rai, 2002). According to Graciano et al. (2006), soil nitrogen absorption efficiency increased with P fertilization in *Eucalyptus grandis*. All plots that received nitrogen and phosphorus fertilizers resulted in better seedlings growth than those that received either nitrogen or phosphorus.

The influence of nitrogen and phosphorus fertilizers application was evident on the content of soil N and P at different depths (Table 3). Soil phosphorus content was significantly affected at all depths while soil nitrogen was affected only at 60 and 90 cm depths. Phosphorus fertilizer tended to increase soil P at all depths and higher rate of P increased soil N to the maximum. Application rate of 46 kg N $ha^{-1}$ with 4 kg P $ha^{-1}$ and 46 kg N $ha^{-1}$ with 8 kg P ha $^{-1}$ tended to reduce soil P at 30 and 60 cm. By contrast application rate of 92 kg N $ha^{-1}$ with 4 kg P $ha^{-1}$ gave the highest soil P at all depth. Rate of nitrogen might be affected by the available phosphorus by varying soil pH. As nitrogen is the mineral nutrient that is taken up at the highest rate by most plant species (Marschner, 1995), it occurs in the soil as various species that bear different charges and influence soil pH. The highest soil nitrogen was also recorded at 92 kg N $ha^{-1}$ with 8 kg P $ha^{-1}$ at 60 cm which gave the least soil P at 90 cm. Similar trend was also shown at the application rate of 92 kg N $ha^{-1/}$and 4 kg P $ha^{-1}$ at 90 cm whereby soil N was least and soil P was highest. Soil nitrogen content is affected by many factors including soil texture, structure and hydraulic conductivity as this influence the movement of nitrogen in the soil. As a result, the applied nitrogen might be accumulated in the soil or move downward or else lost to the air.

Moreover, NP content of the leaf, stem and root was significantly varied by nitrogen and phosphorus fertilizers (Table 4). Application of nitrogen and phosphorus fertilizer increased the nitrogen and phosphorus content of *Eucalyptus globules* wood (Raymond and Muneri, 2000). Rate of nitrogen affected the level of nitrogen in the different organs of *C. edulis*. The highest leaf N was recorded at 46 kg $ha^{-1}$ N whereas the highest stem and root nitrogen were indicated at 92 kg $ha^{-1}$ N. Hanway and Weber (1971) reported that the amount of soil nitrogen affected the relative distribution of nitrogen in the different plant parts of soybean. Allocation of nitrogen to the leaves was prior to stem and root as leaves are the principal photosynthetic organs of the plant. The least leaf and stem nitrogen were recorded at 46 kg $ha^{-1}$N and 8 kg $ha^{-1}$P but an increasing trend in leaf nitrogen was shown as nitrogen applied at 92 kg $ha^{-1}$ combined with 4 and 8 kg $ha^{-1}$P; however root nitrogen showed a decreasing trend at these rates. Combined application of nitrogen and phosphorus fertilizers or phosphorus alone at low rate, reduced leaf and root phosphorus content significantly. However, leaf phosphorus was maximized as the applied P increased to 8 kg $ha^{-1}$. *Podocarpus urbanii* and *Clethra occidentalis* foliar P concentrations was increased by P fertilization (Tanner et al., 1990).

**Table 3.** Effect of nitrogen and phosphorus fertilizers on nitrogen and phosphorus content of the experimental soil at different depths.

| Treatment | | Soil depth (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30 | | 60 | | 90 | |
| N (kgha$^{-1}$) | P (kgha$^{-1}$) | Soil N (%) | Soil P (mgkg$^{-1}$) | Soil N (%) | Soil P (mgkg$^{-1}$ ) | Soil N (%) | Soil P (mgkg$^{-1}$) |
| 0 | 0 | 0.037 | 10.1 | 0.026 | 15.63 | 0.040 | 14.4 |
| 0 | 4 | 0.040 | 15.8 | 0.037 | 15.87 | 0.040 | 13.51 |
| 0 | 8 | 0.042 | 16.35 | 0.049 | 17.10 | 0.048 | 14.9 |
| 46 | 0 | 0.044 | 15.1 | 0.041 | 13.43 | 0.037 | 7.2 |
| 46 | 4 | 0.037 | 8.9 | 0.043 | 8.6 | 0.037 | 10.3 |
| 46 | 8 | 0.049 | 8.4 | 0.047 | 11.33 | 0.044 | 10.1 |
| 92 | 0 | 0.033 | 11.8 | 0.040 | 10.9 | 0.042 | 9.6 |
| 92 | 4 | 0.035 | 17.9 | 0.037 | 17.27 | 0.035 | 17.4 |
| 92 | 8 | 0.051 | 16.2 | 0.049 | 16.9 | 0.047 | 7.4 |
| N | | ns | * | ns | * | ns | ** |
| P | | ns | * | ** | ns | ** | ns |
| N*P | | ns | ** | ns | ns | ns | ns |
| LSD (5%) N*P | | ns | 5.05 | ns | ns | ns | ns |

ns, Non- significant,*, **, significant at P = 0.05 and P = 0.01, respectively.

**Table 4.** Effect of nitrogen and phosphorus fertilizers on nitrogen and phosphorus content in the different organs of *C. Edulis.*

| Treatment | | Nitrogen (%) | | | Phosphorus (%) | | |
|---|---|---|---|---|---|---|---|
| N(kg/ha$^{-1}$) | P(kg/ha$^{-1}$) | Leaf | Stem | Root | Leaf | Stem | Root |
| 0 | 0 | 2.35 | 1.135 | 0.737 | 0.06 | 0.017 | 0.043 |
| 0 | 4 | 1.619 | 1.335 | 1.43 | 0.029 | 0.051 | 0.037 |
| 0 | 8 | 3.40 | 2.165 | 1.645 | 0.136 | 0.048 | 0.050 |
| 46 | 0 | 3.95 | 1.44 | 1.296 | 0.083 | 0.035 | 0.049 |
| 46 | 4 | 1.625 | 1.44 | 2.565 | 0.079 | 0.047 | 0.017 |
| 46 | 8 | 0.955 | 0.96 | 2.165 | 0.074 | 0.047 | 0.039 |
| 92 | 0 | 1.185 | 2.63 | 2.79 | 0.080 | 0.058 | 0.074 |
| 92 | 4 | 2.34 | 2.42 | 2.305 | 0.053 | 0.040 | 0.099 |
| 92 | 8 | 3.195 | 2.485 | 1.915 | 0.047 | 0.055 | 0.056 |
| N | | ns | *** | *** | *** | ns | * |
| P | | ns | ns | ns | *** | ns | ns |
| N*P | | ** | ns | ** | *** | ns | ns |
| LSD (5%) | | 1.88 | ns | 0.75 | 0.01 | ns | ns |

ns, Non- significant,*,**,***, significant at P = 0.05, P = 0.01 and P = 0.001, respectively.

Similarly, foliar phosphorus concentrations of *Zenobia pulverulenta* and *Lyonia lucida* increased in response to enhanced phosphorus availability (Simms, 1987). In another study, addition of NP nutrient solution to *Citrus limonia* increased leaf nitrogen and phosphorus content to a higher level (Ruschel et al., 2004). A decreasing trend in the amount of leaf phosphorus was also found as N rate increased possibly due to increased seedling growth and resulting dilution effect. Likewise, fertilization of *Dendropanax pendulus* and *Hedyosmum arborescens* with N resulted in lower P concentrations (Tanner et al., 1990). On the other hand, roots' phosphorus was highest at 92 kg ha$^{-1}$ N and 4 kg ha$^{-1}$ P while the least was at 46 kg ha$^{-1}$ N and 4 kg ha$^{-1}$ P. In *Cicer arietinum,* phosphate uptake was affected more by nitrogen than phosphorus and severely reduced in low nitrogen condition (Das and Pen, 1981).

### Experiment 2: Date of cotyledon removal

A weekly interval of removing cotyledon after germination significantly affected most of the growth parameters measured (Table 5) except number of survived seedlings

**Table 5.** Effect of date of cotyledon removal on shoot and root growth of *C. edulis* seedlings.

| Day | Plant height (cm) | Root length (cm) | Stem diameter (mm) | Root diameter (mm) | Leaf area ($cm^2$) | Dry weight of seedlings (g) |
|---|---|---|---|---|---|---|
| 7 | 3.5 | 15.0 | 1.9 | 2.2 | 9.9 | 0.3 |
| 14 | 4.1 | 11.6 | 2.0 | 2.0 | 18.4 | 0.5 |
| 21 | 5.5 | 13.3 | 2.1 | 2.4 | 17.7 | 0.7 |
| 28 | 6.2 | 13.2 | 2.0 | 2.2 | 22.4 | 0.8 |
| 35 | 3.4 | 26.7 | 2.2 | 2.1 | 10.0 | 0.4 |
| 42 | 5.5 | 17.9 | 2.2 | 2.4 | 20.9 | 0.9 |
| 49 | 5.9 | 15.2 | 2.1 | 2.3 | 17.9 | 0.6 |
| 56 | 5.7 | 20.7 | 2.0 | 2.1 | 20.0 | 0.9 |
| 63 | 5.3 | 17.1 | 2.1 | 2.3 | 19.3 | 0.7 |
| 70 | 5.6 | 15.0 | 2.1 | 2.2 | 17.4 | 0.6 |
| Control | 5.5 | 24.8 | 2.3 | 2.4 | 35.4 | 1.0 |
| Significance | *** | ** | ns | * | ** | *** |
| LSD | 1.37 | 9.47 | ns | 0.37 | 11.11 | 0.35 |

ns = non-significant, *,**,***= significant at P = 0.05, P = 0.01 and P = 0.001.

(Data not shown).

Removal of cotyledon 7 DAG reduced plant height, leaf area and dry weight of *C. edulis* significantly compared to the control. Along the same line, García-Cebrián et al. (2003) showed significant reduction of seedling growth of *Quercus robur* L when the cotyledon was removed at emergence and 7, 14 and 21 days after shoot emergence.

Plant height increased with delay in cotyledon removal up to 28 DAG where the highest seedling shoot length was recorded. Cotyledon removal on 35 DAG depressed shoot growth of *C. edulis* whereas this treatment resulted in the longest root growth of the seedlings. From the data, it appears that cotyledon contribute more to growth of the shoot during the first four weeks after germination while more nutrient allocation goes to the roots thereafter. Generally, nutrients supply by cotyledon serve for limited time (Krigel, 1967). For both hypogeal and epigeal species, the timing of maximum relative growth, the exhaustion of cotyledon reserves and the attainment of independence from cotyledon all roughly coincided (Hanley et al., 2004). Similarly, cotyledon abscission of *Caesalpinia peltophoroides* took place at 35 days after sowing (Corte et al., 2008).

The highest leaf area and dry weight of seedlings were recorded in plants with intact cotyledon possibly indicates that plants with cotyledon have a better start and can use the available resource efficiently thus increase biomass whereas plants with detached cotyledon, particularly at 7 and 14 DAG have less developed roots and shoot and this might affect their performance at later stage.

## Conclusion

Result of this study indicated that growth of *C. Edulis* has increased with application of nitrogen and phosphorus fertilizers. Application of 92 kg N and 8 kg P $ha^{-1}$ increased height of seedlings by about 134% compared to those of the unfertilized plants. The highest leaf area and total dry biomass of seedlings were obtained by the treatment combinations of 46 kg N with 4 and 8 kg P $ha^{-1}$ that showed increments of about 152% in leaf area and 309% in total dry biomass compared to the unfertilized control plants. With the treatment combination of 92 kg N and 8 kg P $ha^{-1}$ NP, the leaf area and dry biomass weight of the seedlings showed slight decrease in leaf area (22%) and the dry biomass yield (4%) compared to 46/4 kg $ha^{-1}$ and 46/8 kg $ha^{-1}$ NP treatment combination. Thus, the use of 46 and 92 kg $ha^{-1}$ N with 8 kg $ha^{-1}$ P could help to improve growth of *C. edulis* seedlings in areas with low nitrogen and phosphorus status. However, increased levels and split application of the fertilizers particularly that of nitrogen, deserves further investigation in order to enhance growth and establishment of this valuable but very slow growing species.

Moreover, it was evident that *C. edulis* seedlings with attached cotyledon established better and showed enhanced growth compared to early removal of cotyledon. Hence, *C. edulis* cotyledon should be given special attention during early phase of seedling growth for its successful establishment.

## ACKNOWLEDGEMENT

The authors highly appreciate Haramaya University and Sida/SAREC for financial support to carry out this study and also the owner of Hamdail farm, Mr. Mohammed Shito, for allowing his plot of land to be used to conduct the field experiment.

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